Samarawickrama, Sumanthri, et al (eds), 2019, "Re-evaluating Space across disciplines": *Proceedings of the 12th International Conference of Faculty of Architecture Research Unit (FARU), University of Moratuwa, Sri Lanka, December 03, 2019 Colombo* pp. 316–323. ©

BIOGAS AS A SUSTAINABLE ENERGY MANAGEMENT AND SOLID WASTE MANAGEMENT SOLUTION FOR RESIDENTIAL APARTMENTS

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Abstract
In the current global context, attention is being paid towards the sustainability. Moreover, there are many energy sector challenges, which are getting more critical day by day. In order to overcome from such critical energy issues, different strategies are identified by several researchers in the built environment. One such strategy is use of biogas, which advances waste management and it also helps to reduce the solid waste management issues pertaining in the current society due to lack of waste dumping yards. Hence, this paper aims to present the potential of implementing biogas for the apartment buildings as a sustainable energy and waste management solution. Qualitative approach was followed along with the case study strategy. Seven cases were selected for the study purpose. Solid waste types, source of solid waste, waste management procedure of the apartment buildings were identified. Further, under biogas implementation in apartment buildings, benefits, barriers and strategies to overcome from the identified barriers were discussed. The results suggest that effective implementation of biogas system for apartment buildings is a precise solution not only for waste management issue but also for non-renewable energy issues faced by Sri Lanka.

Keywords: *Apartment Buildings; Biogas; Energy Management; Sustainability; Waste Management.*

1. Introduction

As a result of sustainability's potential for solving current global problems and providing for future generations by integrating environmental, economic, and social considerations, it has attracted a great amount of attention in recent years (Mihelcic, Crittenden, Small, Shonnard, & Hokanson, 2003). Sustainability can be defined as a development, which should fit the needs of the present without adding up to the ability of future generations to satisfy their own needs (Brundtland, 1987). Moreover, International Organisation for Standardization 92016) stated that energy management is the procedure of adapting and optimizing energy, with the use of various acts so as to reduce total energy demands per unit of yield while keeping uniform or diminishing total costs of producing the yield from these systems.

There are many energy sector challenges, which are getting more critical day by day such as global fuel-food crisis, overdependence on fossil fuels, and excessive emission of greenhouse gases, global warming, and climate change (Mohanty, 2012). The author has stated that there is a very high demand for energy than ever before due to the growth of population and these conditions arouse the need for efficient renewable energy sources. Further, Mohanty (2012) mentioned that, renewable energy sources are much more needed these days and consequently 'green growth' and 'green economy' can be accomplished via green energy initiatives and development of green energy technologies. As per the findings of World Bank (2013), countries like Sri Lanka, Bangladesh, Pakistan and Nepal, this situation has become much more critical. In many countries in the world, it has become an important objective to utilize renewable energy as it will provide for a clean and sustainable approach to energy production (Lund, Duic, Krajac, & Carvalho, 2007).

There are many sustainable energy sources such as hydroelectricity, wind energy, solar energy, geothermal energy, wave power, biomass, tidal power, and artificial photosynthesis (Stritih, Paksoy, Turgut, Oste, Evliya, & Butala, 2015). Biomass is a basis in the cornerstone in renewable energy projections of the European Union, and biomass will be accounted for 56% of the renewable energy supply in the EU27a by 2020 (Bentsen , & Felby, 2012). Further, authors have stated that biodegradable matter is the highest proportion of the Municipal Solid Waste (MSW), which is when disposed to landfills, form different gases and leachate. Efforts to identify alternative management options for MSW is being a result of concerns over the effects on the environment of the landfill (Facchini, Gronow, Voulvoulis, & Ohandja, 2011). In Sri Lanka, great amounts of MSW are generated pioneering for many

social and environmental issues (Ameen, 2017). In Sri Lanka, great amounts of MSW are generated pioneering for many social and environmental issues. It is noted that 0.40-0.85 kg of waste is generated by one person per year in Sri Lanka and 6400 tons per day is generated whereas the collection of waste is only about 3740 tons per day (Waste Management Authority, 2016).

Biogases can be recognized as an ecological solution, which remarks to constituent like methane and carbon dioxide that are formed by the anaerobic fermentation of biological materials. Biogases are mostly formed from agronomic and biological waste (GE Energy, 2009). As per the finding of Ndzibah (2009), to yield a significant quantity of energy; the waste input should be large enough. The populations of apartment buildings, student hostels, and big companies could be large enough for a rational amount of waste to be produced to fuel the scheme. Biogas generation is an intelligent way of arraying waste. Biogases, advance the waste management and have given biogas-fuelled engines an opportunity to increase the quality of waste management through exploiting the usage of a cost-effective energy source (Ketola, & Salmi, 2010). Thus this paper focuses to discuss the potential of implementing biogas system for apartment buildings as a sustainable energy solution and waste management solution.

2. Literature Review

2.1. CONCEPTS OF ENERGY, AND ENERGY MANAGEMENT

With the increasing population, demand for the energy keeps increasing and it has resulted in energy crisis (Coyle, Simmons, Eugene, & Richard,2014) Energy crisis can be defined as the inability to provide the required amount of energy to the users (Ozturk, Sozdemir, & Ulger,2013). Mainly energy can be categorised into two sources as primary source and the secondary source whereas primary energy is taken directly from the environment while the secondary energy is the change form of the primary energy (Demirel, 2016).

In any organisation, energy cost is considered as one of the key costs, which needs to be saved in order to achieve profits for the organisation (Krishna, & Anuradha, 2016). Thus, energy management is vital for an organisation. Energy management means the process of monitoring, controlling, and conserving energy in a building structure or an organization (Ellsworth-Krebs, & Reid, 2016).

2.2. INTEGRATION OF WASTE MANAGEMENT AND ENERGY

Solid Waste (SW) is defined as the portable objects that have been abandoned by the owners (Bilitewski, Hardtle, & Marek, 1997). In the modern context, priority is given to sustainability due to the resource scarcity (United Nations Environment Programme, 2005 Thus, attention is being paid for strategies like recycling, waste quantity minimization, and conversion of waste into energy (Galante , Aiello, Enea, & Panascia, 2010). Waste is considered as a key issue, which needs to be addressed as it concerns the public health and environment (Wilson, & Rogero, 2015). According to Abouzied, and Chen (2014), waste management in developing countries needs significant improvements.

2.3. WASTE IN RESIDENTIAL APARTMENTS

According to Aiello, Enea, and Panascia, (2010), due to the positive relationship between population and waste generation, waste generation get increased with the population growth. Moreover, authors have stated that it is a critical issue to identify the most suitable method for solid waste disposal. However, with the waste disposal, number of issues like Green House Gas (GHG) emission, leachate generation and different environmental issues get generated (Angelidak, & Batstone, 2010)

According to Yatima, and Arshad (2010), residential solid waste comprises of organic waste, food waste, paper, glass, plastics, metal, aluminium, and textile waste. Further, authors have stated that, organic waste is the most generated waste type in residential buildings while plastic is the second largest waste type generated in residential buildings. For the waste collection in apartment buildings, there are solid waste collection points like allocation of wet and dry bins, and waste collection yard (Waste Management

Authority, 2016). In addition to that, in the report National Building Code (2005), for the waste transportation from different storeys to the collection area in the ground floor, there should be two separate garbage chutes as wet and dry waste. According to Consonni and Vigano (2012), when waste is managed properly in residential buildings, economic benefits can be achieved by implementing strategies like use of biogas system instead of LP gas system.

2.4. BIOGAS SYSTEM

Depending on social, economic and environmental criteria, integration among energy and waste management may vary and by using waste to energy technologies, environmental friendly energy production can be achieved (World Energy Council, 2013). In the current context, most common waste handling methods are identified as recycling, mechanical-biological treatment, landfilling, composting and waste to energy methods (Psomopoulos, Bourka, & Themelis, 2009). Moreover, authors have stated that, through waste to energy technologies, different types of waste are converted into valuable energy sources. Authors have also said that, through organic waste, biofuels can be produced. Furthermore, in the modern world, research projects are being conducted to identify the technologies, which can be used to convert waste into energy (Consonni & Viganò, 2012).

According to Al Seadi, Rutz, Prassl, Köttner, Finsterwalder,and Volk, (2008), in many countries sustainable waste management have become a key political priority, representing a vital share of the common efforts to reduce greenhouse gas emissions and pollution and to mitigate global climate changes. Further, authors have identified biogas as a solution to the organic waste generation. Moreover, Angelidak, and Batstone, (2010) stated that, biogas can be produced through Anaerobic Digestion (AD) of slurries and animal manure as well. In addition to that, Preibler, (2007) has explained AD is a microbiological procedure that use to decompose organic matters. When it comes to the benefits of biogas system through the conversion of waste, there are benefits like use of biogas an energy source, environmental management, efficient and flexible biogas usage, and use as a fertilizer (Al Seadi et al., 2008; Sri Lanka Standards Institution,2017).

3. Research Methodology

In order to check the feasibility of implementing biogas system to the residential apartments as a sustainable energy solution and solid waste management solution, qualitative approach was followed in the study. Case studies were selected as the research strategy and seven cases were selected for the study and Table 1 shows the profile of the cases. Semi structured interviews, documentary review and non-participatory observation methods were used as the data collection techniques. Respondent details of the seven selected cases are provided in Table 2.

Table 1 : Profile of the Cases

Case	Description
A	• The apartment is a 31 storeyed building and has 122 apartment units. • Apartment has roof top, swimming pool, kiddie's pool, banquet hall recreation areas, gymnasium, lounge, building management office, drivers lounge, and a heliport.
B	• The apartment is a twin building and one tower has 23 floors. • The apartment has swimming pool, club house, gymnasium, kiddie's pool, and a car park.
C	• The apartment is a twin building and one tower has 37 floors • The apartment has swimming pool, gymnasium, kiddie's pool, and a car park.
D	• The apartment is a 45 storeyed building and has 160 apartment units. • Apartment has swimming pool, kiddie's pool, banquet hall recreation areas, gymnasium, building management office.
E	• The Apartment has three tower and each tower has 38 floors.

	• The apartment has swimming pool, gymnasium, kiddie's pool, and a car park.
F	• The apartment is a 10 storeyed building and has 61 apartment units. • Apartment has swimming pool, gymnasium, building management office
G	• The apartment is a 32 storeyed building and has 120 Apartment units. • Apartment has car park, swimming pool, gymnasium, and function hall.

Table 2 : Details of the respondents

Case	Respondent	Respondent Profile	Experience
A	A1	Executive Engineer	15 Years
	A2	Executive Facility Manager	5 Years
B	B1	Property Manager	40 Years
	B2	Facilities Executive	3 Years
C	C1	Executive Engineer	30 Years
	C2	Property Manager	22 Years
D	D1	Facility Manager	5 Years
	D2	Executive Engineer	16 Years
E	E1	Property Manager	25 Years
F	F1	Property Manager	10 Years
	F2	Facility Engineer	6 Years
G	G1	Facility Engineer	15 Years

For the analysis of the collected data through the semi structured interviews, content analysis was used along with the N-Vivo computer software. Section 4 presents the analysed data from the semi structured interviews.

4. Results and Discussion

In order to identify the importance of integrating energy management and waste management, current waste generation, existing waste management methods and current waste management procedures were investigated and presented in this section.

4.1. SOLID WASTE GENERATION AND WASTE MANAGEMENT PROCEDURE IN SRI LANKAN APARTMENT BUILDINGS

For the implementation of biogas system in an apartment buildings, it is necessary to identify the waste generation methods in the building. When it comes to the case study findings, it was evident that in all the cases, similar types of solid waste get generated and presented in Table 3 with the source of waste generation of the selected cases.

Table 3: Waste Types and Source of Waste Generation

Waste Type	Source
Food waste	Apartment kitchen, Cafes, Function halls
Paper waste	Apartment units, Condominium offices and Cafes
Plastic waste	Apartment units
Glass waste	Apartment units
Sewage	Apartment units, Condominium offices, Cafes and function halls
Garden waste	Gardens
Others	Maintenance waste form the maintenance division, Waste water from all the apartment units and car washing bays

As per the literature findings, it was identified that biogas can be produced in apartments only through biodegradable waste. The case study findings show that biodegradable solid waste types as food waste, sewage, and garden waste. While analysing Table 3, it could observe, apartment units are the main

source of waste generation. Furthermore, from the findings it was evident that within a week, out of the generated solid waste, food waste is the highest waste type generated in all seven cases while the less amount of waste is generated through garden waste due to the limited garden space in apartment buildings. Figure 1 illustrates main waste type generate in the apartment.

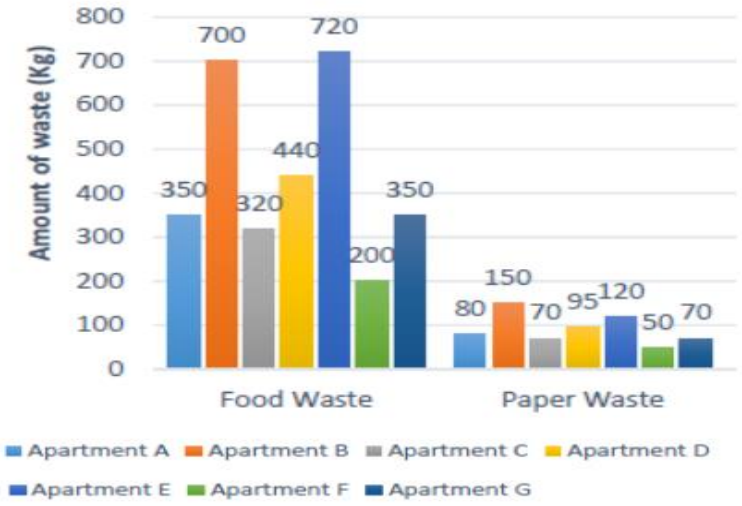

Figure 1 : Main types of waste generation in apartments

Moreover, the study revealed that for the production of bio gas, as the inputs food waste and garden waste can be used. Although sewage waste can be used for the production of bio gas, in the current context of the waste quantification, sewer waste is not taken into consideration. In addition, it was identified that there is a positive relationship between waste generation and the average occupancy of the building based on case study findings. Thus, when the occupancy gets increased waste generation too get increased.

When considering about the waste management procedure in the selected seven cases, except one, all other cases follow the same method. As the initial stage of the waste management procedure, apartment unit owners do the point wise waste segregation in their own apartment units and by using the garbage chute waste is transferred to the ground floor from each storey of the building. Moreover, it was identified that once the waste is collected in their own apartments, they are brought into the shaft room where waste is segregated as for a bin arrangement of paper, plastic and glass waste. Similarly, food waste is also collected in each and every apartment unit and brought to the shaft area and transferred from the garbage chute to the ground floor garbage room. However, in Case C, separate waste bins have been allocated for each storey of the apartment and they are being transferred to the ground floor garbage collecting area by the janitors. Further, in all seven cases, after collecting them to the ground floor, waste is given to the Municipal Council for the disposal.

4.2. POTENTIAL OF IMPLEMENTING BIO GAS SYSTEM FOR APARTMENT BUILDINGS

To implement biogas system for the apartment buildings, possibilities, benefits, barriers and ways of overcoming the identified barriers are discussed in the following sections.

4.2.1 Possibilities and Benefits of Implementing Biogas System

From the collected data through the semi structured interviews, all the twelve (12) respondents of the seven (07) cases believed that there is a possibility of implementing a bio gas plant in the building. Out of the twelve respondents, respondents of B1, C2, and D2 of the Cases B, C and D stated that it is a good decision, if the biogas plant is designed at the initial stage of the building as it needs to look into some technical and safety aspects in the installation.

By implementing a bio gas system in an apartment building, the study identified that there are benefits like environmental, economic and social. When it comes to the economic benefits, as per the respondent A1 stated that, current cost of LP gas usage in Case A on average basis is Rs. 35,000.00 in every two months and if bio gas is implemented in the apartment building, then this cost can reduced dramatically. All most all the respondents of the seven cases stated that, use of bio gas in their apartment buildings, economic benefits can be enjoyed by the savings through the shifting of LP gas usage to bio gas. Moreover, respondents A1, and F2 of Case A and Case F, highlighted that waste transportation cost savings also can be gained through the use of bio gas system. Furthermore, in the process of bio gas production, there are by products like compost. By selling these compost as fertilizer for the farmers, economic benefits can be gained.

When it comes to the social aspect, in order to use bio gas in the apartments, recycling needs to be carried out. Thus, biogas contributes more towards sustainability aspects such as environmental, economic and social. Furthermore, almost all the respondents have agreed that through the waste recycling, sustainability is achieved by the buildings and with the minimization of non-renewable energy usage, solutions can be provided to the world energy crisis.

4.2.2. Challenges and Barriers for Implementing Biogas System

For the successful implementation of the bio gas system, some barriers were identified as, difficulties in applying new system to an existing design, space limitation, unawareness about the biogas system, safety issues, inconsistency of the waste generation, difficulties in finding the capital cost for the instalment of the biogas system, and difficulties in finding new resources and presented in Figure 2.

Name	Files	References
Implementing Challenges and barriers of biogas system in the Apartment Buildings	12	39
To applying a new system to the current design	9	9
Space limitation	8	8
Unawareness of about biogas system	8	8
Safty issues	4	4
Insufficient waste generation	4	4
Finding the initial cost for implementing	4	4
Finding new resources	2	2

Figure 2: Challenges and barriers

Respondents A1, and D1 of Case A and Case D stated that, if implementation of bio gas system was not in the initial plan of the apartment, it will cause issues in implementing service lines for the bio gas system. Further, respondent B1 explained that, as the space is limited in an apartment building, construction of biogas plant is a difficult task and need to be considered during the planning stage.

4.2.3. Strategies to Overcome the Barriers when Implementing Biogas System for Apartments

As per the findings, to implement a biogas system in an apartment building, awareness needs to be provided to emphasis the benefits of using the biogas system. In order to implement biogas plant in the apartment awareness program should be conducted. By doing that attitudes of the condominium occupants can be changed in a positive way to implement the bio gas plant in the apartment. Further to that, to change the negative attitudes of the condominium council it is necessary to aware them regarding the economic benefits as well as the environmental benefits that could be gained from installing a biogas plant in the apartment. Moreover, respondents highlighted that as the initial stage, awareness needs to be given to the apartment unit owners.

Furthermore, in order to overcome from the limited space issue, respondents D1 and F1 stated that, use of an open area in the garden or else to construct biogas reactors in the underground. To overcome from the safety issue, existing safety methods needs to be upgraded with the modern technologies. Further, respondent D1 highlighted that with the use of modern technological safety system as a method for detection and protection system and to establish ventilated area in the apartment.Moreover, through a feasibility study, capabilities and in-capabilities of biogas plant operation can be identified and through that inconsistency of the waste generation can be overcome. To overcome from the issues related to the installation of service lines, existing LP gas lines can be used to distribute the biogas to the building.

5. Conclusions

Potential of implementing biogas system through solid waste management in an apartment buildings was the main focus of this paper. The study adopted case study strategy to investigate current waste management systems, type and sources of waste generated in the apartment buildings. The study revealed that food waste identified as main key solid waste type and chute and bins are used to collect waste from each unit and finally collected them by the municipal council and dispose.

Main benefits of implementing biogas system were identified in terms of economic, social and environmental while there were barriers like difficulties in applying new system to an existing design, space limitation, unawareness about the biogas system, safety issues, inconsistency of the waste generation, and difficulties in finding the capital cost for the instalment of the biogas system. Further, the study revealed that those barriers can be overcome through awareness programs, space management, and conducting feasibility studies on capabilities and in-capabilities of the biogas plant.

All the respondents believed that there is a potential of implementing biogas system for the apartment buildings and identified it is a sustainable solution for current waste and energy crisis faced by the country.

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